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MONTHLY PROGRESS REPORT

FOR

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INDOOR ENVIRONMENT DEPARTMENT

Environmental Energy Technologies Division
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Notice

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INDOOR ENVIRONMENT DEPARTMENT

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1. Energy Performance of Buildings

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510-486-4022

A. Infiltration, Ventilation, Indoor Air Quality (DOE-IVIAQ Task 1.0)

Sponsor(s): DOE-EE
Collaborator(s): University of Alberta

Background

Using between 2-4 Quads of energy, infiltration is a major energy expense in existing envelope-dominated buildings. Much of this project is devoted to the characterization and optimization of infiltration in small buildings. Model development, instrumentation design, test methods, analysis and stock characterization are all continuing pieces of the work in this area. Understanding the impacts of infiltration and ventilation for both energy and indoor air quality is done through modeling and measurement. Combined heat and mass transport modeling (e.g. in the infiltration heat recovery project) is necessary to accurately determine energy use and potential retrofits.

In new construction, infiltration is much less and does not normally provide sufficient ventilation for acceptable indoor air quality. Accordingly this project supports ventilation standards through scientific research and also participation in consensus standards and code support. Max Sherman is chair of ASHRAE's Residential Ventilation standard (62.2P) and also serves on the non-residential standard. Data collection and analysis of air tightness of new construction is currently in progress.

Technology transfer and implementation support activities to state, federal, and international groups is a continuing effort. LBNL represents the US at Annex V of the IEA/ECBCS project, the Air Infiltration Centre. LBNL staff strongly support ASHRAE, ASTM and other consensus activities as well as assisting others in program and code development. Scientific and popular articles are also used to assist users in making use of DOE-funded research.

May 2001

The LBL version of the paper on infiltration heat recovery intended for the Buildings VIII conference was completed and sent to the printers. Progress on the IHR simulations continues, but is slow due to limitations of the CFD code.

Preparations were made for the ASHRAE meeting to be held in Cincinnati. New drafts of Standard 62.2P were sent to the committee. Recommendations were made to ASHRAE to modify the Scope of the standard to reduce concerns of some special interests.

Work on the air leakage database was put on hold because of the availability of key resources, but there should be no impact on deliverable dates relating to this task.

The DOE program manager made a site visit and reviewed the current workplan and potential new tasks for FY02 and beyond. LBL staff participated in DOE planning activities related to new initiatives in retrofit research.

B. Residential Envelopes and Commissioning

PIER Residential Commissioning Project
Sponsor(s): DOE, California Energy Commission (CEC)
Collaborator(s): None

Background
Currently, houses do not perform optimally or even as many codes and forecasts predict, largely because they are field assembled and there is no consistent process to identify deficiencies or to correct them. As a step toward alleviating this problem, the Public Interest Energy Research (PIER) program of the California Energy Commission (CEC) is funding our research project to lay the groundwork for a residential commissioning industry in California. The vision is that this industry will focus on providing end-use energy and non-energy performance assurances for new and existing houses.

To accomplish the goals of this 30 month-long project, which began in September 1999, scientific research methods are being used, with oversight by industry stakeholders and the CEC. These methods include field data collection, laboratory measurements, simulation, and analysis of existing and newly acquired information. We have already completed and published a literature review of existing information on commissioning. We are nearing completion of our metrics, diagnostics, and norms study to ascertain what potential benefits one can realistically expect from residential commissioning. We are also beginning to write a commissioning guide that will allow non-experts to achieve these benefits. Initial project results have already been presented at two industry meetings. Further efforts are underway to disseminate results through various other meetings and publications.

May 2001
We received minor editorial review comments this month on our metrics and diagnostics evaluation final report (LBNL-45959), which we submitted for review to the CEC Contract Manager and Project Advisory Committee (PAC) in April 2001. We anticipate receiving further comments by mid June 2001. Some comments have been delayed slightly, because the CEC Contract Manager was replaced in May. All comments will be incorporated by the end of June 2001. We expect that the final

document will be posted on the LBNL residential commissioning website for public access shortly thereafter.

This month, we carried out further work to complete two papers for ASHRAE symposia that will be held next summer in Honolulu. One paper is entitled "An Evaluation of Refrigerant Charge Diagnostics for Commissioning Residential Cooling Systems" (LBNL-47476). The other is entitled "Evaluation of Flow Hood Measurements for Residential Register Flows" (LBNL-47382). We expect to submit both papers for external review well before the August 2001 deadline.

Work began this month to develop a new, simple, inexpensive non-powered flow hood for measuring return grille airflows, with the intent of also using it to measure air-handler airflow. Ecotope and The Energy Conservatory have recently developed an "orifice plate" to measure air-handler airflow across the filter space in an air-distribution system. This device is installed inside the air-handling system in place of the filter. However, it is expensive (about $1,000) and is difficult to use (because it must be mounted inside the system). Both issues are barriers to widespread use by contractors. We anticipate the device that we are developing will be much less expensive (about $200 to $300) and much easier to use (external rather than internal mounting). Initial laboratory and field tests will begin in June 2001.

We completed the draft report on our potential value study in May 2001. That study is demonstrating the value of commissioning new and existing California houses. Based on internal review comments within the Energy Performance of Buildings Group, we are carrying out further simulations to include cases that represent a broader range of houses. In particular, our initial simulations emphasized the coincidence of all likely commissioning opportunities in a house (the "poor" cases). The newer simulations are attempting to represent "typical" cases, in which not all commissioning opportunities occur together. To accomplish this, we are using housing stock characteristics to determine weighting factors that we can in turn use to estimate which commissioning opportunities might typically occur together. By the end of June 2001, we expect to complete this work and submit our report on it to the CEC Contract Manager and PAC.

During May, we continued preparing to host the fourth PAC meeting and a one-day workshop on the day after that meeting. The purpose of the workshop is to discuss the first draft of the commissioning guide that we began preparing this month. We expect the draft guide will be complete by mid July 2001. In the workshop, we will present the guide piece by piece with a brief overview and then allow most of the time for discussion from the attendees. To allow sufficient time to review project reports and the commissioning guide, we plan to hold these meetings on August 16 and 17, 2001 in Sacramento. We have invited 46 people to the workshop, including DOE, EPA, and HUD staff; utility representatives; HVAC contractors; building scientists; diagnosticians; and home energy raters.

C. Residential Distribution and HVAC Systems

Thermal Distribution System Figures of Merit
Sponsor(s): DOE, CIEE
Collaborator(s): None

Background
Forced air thermal distribution systems in residences typically lose about 30% of the energy they consume. Because this is a large fraction of the energy consumed by the HVAC system, it is important to be able to provide good estimates of thermal distribution system efficiency. To accomplish this we are developing an ASHRAE Standard to determine the distribution system efficiency of forced air (and hydronic and electric) systems. Also, we have developed sophisticated forced air distribution system computer simulations that are being used to identify potential duct system improvements. These figures of merit are already being used by several authorities (e.g. California Energy Commission and Environmental Protection Agency).

May 2001
Voting was complete this month on the new draft of ASHRAE Standard 152P. The committee voted to send the new draft to ASHRAE for its second public review, and the new draft was duly submitted to ASHRAE this month.

We have completed an investigation (that used the proposed ASHRAE 152P calculation method) into the reductions in duct system efficiency when system air flows and capacities are reduced, and how this decrease in duct efficiency may offset increases in part-load equipment performance. This analysis was expanded to include design weather condition calculations of duct efficiency that showed the changes in efficiency due to reducing duct leakage or adding insulation were approximately double those for the seasonal energy use calculations. The lower design condition efficiencies and greater sensitivity to duct changes are important for estimating equipment sizing and the effects of Time Of Use pricing, where the energy costs are greater at these peak conditions.

We have continued our discussions with duct leakage measurement practitioners and researchers in order to answer negative comments made on the recent ASTM ballot for the draft Duct Leakage standard. A draft report on the technical background and field-testing of the DeltaQ duct leakage test procedure was written this month. This report will be useful in order to reach an agreement on the future of the draft standard.

For the ASTM Longevity standard we are participating in an ongoing discussion to attempt to reach a compromise regarding the temperature limits for testing that will satisfy the commenters and sealant manufacturers. These discussions include providing testimony for the California Energy Commission (CEC) on the technical reasons for not allowing duct tape to be used on ducts. We have also begun

preparation of materials for a hearing to be held at the CEC where we will provide additional testimony in support of the CEC against challenges made by the duct tape industry.

The duct board splitter boxes and round-to-round sheet metal connections continue to be tested in the duct sealant longevity apparatus. Preliminary leakage testing indicates that the duct board splitter boxes have significant leakage before testing was started and have become significantly more leaky as testing continues. The round-to-round connections have not become as leaky as the splitter boxes, but they have significant visual degradation.

We met with our DOE program manager to discuss the progress of our current research and plan for future work. New tasks that were proposed include equipment sizing strategies and comfort evaluations. In addition, the following planning activities were also proposed:

- Development of guidelines, software tools and methods of test for air distribution within a house. This includes issues such as proper distribution to all rooms, reducing the amount of ducts (length of duct run and surface area) used in a system, reducing fan power requirements (using efficient fans and non-restrictive ductwork).
- Improvement and implementation of duct design procedures, particularly the ACCA series of manuals for HVAC system design.

Distribution System Measurements
Sponsor(s): CIEE, DOE
Collaborator(s): Richard Heath & Associates, CA State University-Chico

Background
Estimates of residential HVAC system performance require measurements of several characteristic parameters. We are writing standard test procedures (through ASHRAE and ASTM) for the building industry to use. This includes development of new test procedures (e.g., the DeltaQ test for residential duct leakage) and evaluation and improvement of existing procedures. Both field and laboratory testing are being used to identify key aspects of distribution system performance so that these systems can be improved in both new construction and retrofits of existing buildings. The field measurements give a baseline for estimating peak demand and energy consumption. The laboratory measurements allow development of test procedures and equipment under controlled conditions.

May 2001
We are continuing to perform detailed analysis of the DeltaQ test method and results based on over 100 tests performed in conjunction with CSUC and the tests that EPB has done. A draft report on these DeltaQ tests was completed this month. This report

includes derivations of the DeltaQ analysis, repeatability testing of the DeltaQ test and comparison of the DeltaQ test results with duct pressurization test results.

Field-testing of a house in Fresno, CA, continued this month. This house is being continuously monitored for several months to determine duct system losses due to continuous air handler fan operation. In addition, the individual room-by-room measurements of air temperature and delivered energy (at each register) will be used to evaluate how well the thermal distribution system serves individual rooms. Both of these issues will potentially be included in future versions of ASHRAE Standard 152P. A data acquisition system is monitoring the building and HVAC system energy performance by measuring ventilation air flows, temperatures in the house and HVAC system and weather conditions. The HVAC system is being operated in two modes. In the first mode, the air handler runs continuously and in the second mode, the air handler cycles with furnace operation. We are alternately operating the house in these two modes a few days at a time so that we can have results for similar weather and house conditions for both modes. Data from this system is being downloaded daily as a check on the system status. Due to changes in weather we have completed our heating operation measurements and have switched over to cooling system operation.

Laboratory testing of flexible plastic ducts and duct fitting losses continued this month. This work is determining the losses associated with many fittings commonly found in residential duct systems that are not currently included in many design methods. This includes testing the losses for flexible plastic duct in several configurations: stretched tight, normal, compressed and for several bend angles. Initial analysis shows that the pressure drops in plastic flex duct is much higher than for sheet metal. In addition, we are finding that typical pressure drops based on standardized calculation procedures (e.g., in ASHRAE Fundamentals) are underestimated. We are also developing more accurate estimates of the effect of longitudinal compression of plastic flexible duct. These compression effects are of considerable interest because field installations of ducts rarely have the flex duct cut to the correct length and it is common to see considerable excess flex duct. The full scale residential HVAC system for laboratory testing of measurement methods and duct system pressure losses is currently undergoing shakedown exercises to ensure correct operation before we begin in-situ loss measurements and flow capture hood evaluations.

We have begun development of a flow measurement device that can be used to estimate register and air handler flows. The focus is on a device that is simple and very cheap to construct and very easy to use. This device will be evaluated on the full-scale system and in our field tests later this summer.

The laboratory testing of coil fouling continued this month together with comparison of simplified analytical models to measured data. The comparisons indicate that the models require further development, but they have the right general trends. The laboratory testing this month continued the experiments that use larger diameter

particles. Work is continuing on the preparation of papers discussing the coil fouling experiments and modeling.

Innovative Duct Technology
Sponsor(s): DOE
Collaborator(s): PEG

Background
This DOE STTR is developing a new forced air duct system that uses simple snap together fittings that eliminate duct leakage and many duct system installation problems. Our contribution to this work is to perform field and laboratory testing of the new duct assemblies and to provide commentary and assistance in development of the final design.

May 2001
We are waiting for the duct connection prototypes. There have been production delays for development of sheet metal forming tooling, but PEG has been working hard to overcome these problems.

D. Commercial Distribution and HVAC Systems

Performance Characterization of Thermal Energy Distribution Systems in Commercial Buildings
Sponsor(s): DOE-EE, CEC
Collaborator(s): None

Background
The overall goal of the LBNL Commercial Thermal Distribution System research program is to provide analyses, tools, and technologies geared toward improving the energy, comfort, and indoor air quality performance of these systems. In particular, the goal of the DOE project is to characterize the performance of thermal energy distribution systems in light commercial buildings (floor area between 2,000 and 10,000 ft^2) in non-sunbelt regions, i.e., outside of California. A related California Institute for Energy Efficiency (CIEE) project that we are carrying out involves similar efforts, but in the Sacramento Municipal Utility District (SMUD) and with longer, more extensive monitoring. Our companion California Energy Commission (CEC) project is developing metrics that can be used for these purposes. The latter project will also create useful scientific data and test methods that will facilitate design and evaluation of the energy and environmental performance of thermal distribution systems within both light commercial and large commercial buildings (floor area greater than 10,000 ft^2).

May 2001
This month, we continued to communicate with C. Klaassen at the Energy Resource Station in Iowa to identify light commercial buildings for testing in late summer 2001.

In mid May, we selected five buildings from the list of 14 provided. We are planning a two-day site visit in early July 2001 to verify that the selected buildings are indeed suitable.

Funding of our CIEE project to characterize the performance of thermal energy distribution systems in light commercial buildings in Sacramento was approved this month. We continued communicating with B. Vincent of SMUD to identify four systems to test before and after aerosol sealing during the cooling season in July and August 2001. Our tests will include measuring duct leakage, temperatures in the air distribution system and surrounding spaces, airflows, and system operating pressures. SMUD will be responsible for monitoring electricity used by the HVAC systems. No buildings for testing have been identified yet, but we expect to do so by the end of June 2001. We will carry out pre-screening diagnostics then to verify that the selected buildings have leaky enough air distribution systems to warrant monitoring and sealing.

We also continued our communications with various outside consultants, building engineers, and management staff to identify large commercial building systems suitable for our duct system characterization and aerosol sealing studies for the CEC. We are particularly interested in a State building and a Federal building that are located in Sacramento. One reason is that we may be able to coordinate our efforts with external studies; another is that their air-handling systems appear to be easier to test compared to the other buildings we have considered. In June 2001, we expect to visit these two buildings to determine whether they are indeed suitable. Because large commercial buildings are largely internal-load dominated, we plan to test these types of buildings later in the year, after we test the more external-load-sensitive light-commercial buildings.

Development and Testing of Aerosol Sealing Technologies
Sponsor(s): DOE-EE
Collaborator(s): None

Background
This project is developing and evaluating aerosol-based sealing techniques that could be used in large duct systems.

May 2001
Aerosol sealing rates depend on particle size distribution, which in turn depends on many conditions (e.g., bulk airflow, sealant injection rate, and leak location relative to the particle generation location). To further understand the effects of bulk airflow on the behavior of our new compact aerosol duct sealing injector, we used a cascade impactor to measure the aerosol size distributions at two different bulk airflows in a 10-inch diameter duct. During these tests, we used an "optimal" sealant injection rate of 18 ml/min with no dilution, and measured the particle distributions 25 feet downstream from the injection location. For a 100 cfm bulk airflow, 70% of the particles were in the 5

to 15 micron size range; 17% had a particle size of 5 micron or less; and the remainder (13%) was larger than 15 microns. With a 50% reduction in bulk airflow (to 50 cfm), much fewer of the particles (almost 30% instead of 70%) were in the 5 to 15 micron size range, and substantially more were in the smaller and larger size ranges (38% were 5 microns or less and 32% were larger than 15 microns. For comparison purposes, we plan to repeat the experiment during June 2001 using our old injector.

Dirt adhering to tacky aerosol particles deposited on duct internal walls could lead to increased duct friction loss over time. We have located an alternative aerosol sealant ("Magic Sealer") that might reduce this friction loss. Unlike the "Duct Seal" sealant that we use now (which remains tacky), the new sealant loses its initial tackiness. We expect the new sealant will be less likely to retain dirt. Our initial tests this month show that the new sealant can seal leaks, but it takes about three times longer compared to the other sealant. Also, the new sealant appears to be susceptible to partial blowout by high pressures at leaks. We believe this occurs because the sealant is no longer tacky.

OUTSIDE CONTACTS

May 2001

In mid-May 2001, Max Sherman met with Martha Brook (the CEC Contract Manager) in Sacramento to discuss follow-on activities for the residential commissioning project.

Max Sherman was interviewed by CNN regarding our work on duct sealants.
Iain Walker was interviewed by the Canadian Newspaper the "National Post" for an article on duct sealants.

Iain Walker and Darryl Dickerhoff met with Don Chalmers and George Warren of SMS to discuss the development and manufacture of innovative duct sealing and connecting fittings.

In mid-May, M. Modera, M. Sherman, D. Wang, and C. Wray met with Esher Kweller of DOE and Steve Cooke of DOE/NETL at LBNL to review the status of our Commercial Thermal Distribution System research.

INDOOR ENVIRONMENT DEPARTMENT

2. Ventilation and IAQ Control Technologies

W.J. Fisk, A.J. Gadgil, R.G. Sextro, A.T. Hodgson
510-486-5910

A. Ventilation Measurement Methods (DOE IVIAQ Task 3.5)

Measuring Outside Air Flow in AHUs
Sponsor(s): DOE-EE
Collaborator(s): none

Background

Current ventilation data indicate that there are wide variations in ventilation rates among buildings. In many buildings, minimum ventilation rates are well below or above the rates in applicable standards. These data and our research experience demonstrate that the common methods of measuring and controlling the rate of outside air supply by air handlers are often inadequate. The consequence is poor air quality in some buildings and excessive ventilation rates in other buildings. Starting in the middle of FY 2000, we initiated a new research effort on methods of monitoring and controlling rates of outside air supply by air handling systems. The work plan is broken into five categories:

- Communication with industry (ongoing throughout the project)
- Literature / hardware review and Common Practice Survey
- Controlled rooftop (or laboratory) experimental evaluation of technologies
- Field studies (small effort before and larger effort after controlled experiments)
- Work with a professional organization to develop performance testing protocols

May 2001

Lists of engineers / contractors, facility managers, and test and balance contractors were assembled for the three cities in our survey: Minneapolis, St. Louis, and Miami. Developing these lists required considerably more work than anticipated, particularly the list of facility managers.

B. VOC Sources, Emissions, and Controls (DOE IVIAQ Task 3.7)

Modeling Emissions of VOCs from Indoor Materials
Sponsor(s): DOE-EE
Collaborator(s): Virginia Tech

Background

Al Hodgson is working in collaboration with professor John Little and graduate students Steve Cox and Deept Kumar of Virginia Tech (VT), Blacksburg, VA to produce

mechanistic models that describe the emissions of volatile organic compounds (VOCs) from various solid materials used in buildings. The primary objectives of this research are to better understand and to be able to predict the impact of VOC sources and sinks in the indoor environment. An ancillary goal is to create a less-expensive and superior alternative to emissions testing in environmental chambers for estimating VOC emission rates from building materials. This effort has recently resulted in the development and validation of a physical model for predicting the rate at which VOCs are emitted from vinyl flooring, an exemplary solid-phase material. The key model parameters are the initial concentration of a VOC in the material phase, the VOC material/air partition coefficient and the VOC material-phase diffusion coefficient. These parameters are independently measured using novel methods developed as part of this project. The research collaboration is now attempting to extend the physical model to predict VOC emissions for simple bi-layered materials.

May 2001

Revisions were made in response to reviewers' comments to the manuscript entitled, "Modeling the Reversible Sink Effect in Response to Transient Contaminant Sources." The manuscript was resubmitted to *Indoor Air*. Additional literature on the diffusivities of VOCs in various building materials was obtained and reviewed. Several of these studies show that gypsum board, the most common interior surface material in houses, is highly porous. The collaborators discussed research ideas related to transport of airborne contaminants through wall systems.

Impacts of Ventilation Rate on VOC Concentrations and Emission Rates (DOE IVIAQ Task 3.7)

Sponsor(s): DOE-EE

Collaborator(s): U.C. Berkeley, Center for the Built Environment

Background

A ventilation-rate intervention study (section 3A) is being conducted to quantify the relationships of worker performance in a call center with ventilation rate and air temperature. The three-month study period was concluded in October. The building's air handling systems were operated at three constant outside-air supply rates. The minimum rate corresponded to applicable code requirements. Ventilation rates were periodically changed over 12 weeks. The schedule incorporated both weekly and daily adjustments of the outside air damper settings. Building temperatures, relative humidities, CO_2 concentrations, and airflow rates in the air handling systems were monitored and recorded. The research team is using the opportunity provided by this intervention study to quantify the effects of building ventilation rate on the concentrations and source strengths of VOCs, including formaldehyde. Air samples for VOCs were collected from outdoor air and the four building air returns on a single mid-week day during seven weeks. The air samples were qualitatively analyzed to identify the predominant compounds present in the building. A suite of 50 compounds was

quantitatively analyzed. Measured airflow rates are being used to calculate VOC emission rates for the four air handler zones.

May 2001
There were no new results this month.

Comfort and Health-Based Guidelines for Indoor Concentrations and Material Emissions of VOCs (DOE IVIAQ Task 3.7)
Sponsor(s): DOE-EE
Collaborator(s): Building Ecology Research Group, Health Effects Institute

Background
The overall goal of this project is to develop a methodology for establishing comfort and health-based guidelines for indoor concentrations and material emissions of VOCs. Hal Levin of the Building Ecology Research Group, Santa Cruz, CA and J. Ten Brinke of the Health Effects Institute, Cambridge, MA, are collaborating with A. Hodgson on this effort. A database has been developed that contains approximately 90 individual VOCs spanning a broad range of volatility and chemical functionality. Most of these compounds have been detected in North American houses and office buildings. Available data for the 90 compounds on occupational inhalation exposure guidelines, sensory irritation measured by mouse bioassay, odor thresholds, and chronic reference exposure levels established by the State of California have been summarized from the literature and incorporated into the database. A methodology for evaluating the potential for a compound to elicit a comfort or health-based response among building occupants is currently being evaluated.

May 2001
There were no new results this month.

Joint Research and Demo Project on Energy Efficient and Healthy Homes (DOE IVIAQ Task 6.0)
Sponsor(s): DOE-EE
Collaborator(s): Florida Solar Energy Center

Background
A primary objective of this research is to determine the sources and entry pathways of the most abundant and persistent VOCs in new houses, including houses with energy-efficient features. A. Hodgson, in collaboration with Subrato Chandra and David Beal of the Florida Solar Energy Center (FSEC), Cocoa, FL, is currently conducting a field and laboratory study to identify and quantify the sources of terpene hydrocarbons, formaldehyde, other aldehydes and carboxylic acids in a new manufactured house. The house is located in Florida and is used daily as a sales model. The manufacturer supplied a detailed list of all of the materials used in construction of the house.

Specimens of the major materials were obtained from the production facility. Laboratory chamber tests were conducted with these materials to measure the emission rates of the target VOCs. These emission rates were used with the material quantities to estimate whole-house emission rates. The predicted emission rates were compared to emission rates calculated from the measured ventilation rates and the concentrations of VOCs in the house approximately four months after its completion. For 11 of 14 predominant compounds, the predicted concentrations agreed within a factor of two.

May 2001
There were no new results this month.

C. Ventilation and Indoor Air Quality Studies

Assessment of Particle Control Technologies (DOE IVIAQ Task 3.6)
Sponsor(s): DOE-EE
Collaborator(s): Helsinki University of Technology

Background
The objectives of this effort are to quantify the reductions in indoor concentrations of particles, from various sources, that result when a variety of air cleaning measures are employed, and to characterize the associated energy costs and total costs. This work is based on analyses of existing data and modeling. The sources of particles considered are outdoor air (fine mode), dust mites, cats, environmental tobacco smoke, and droplet nuclei from coughs and sneezes. The particle air cleaning options include filtration, with various filter efficiencies, and electronic air cleaning. We are evaluating air-cleaning equipment installed within HVAC systems and stand-alone devices.

May 2001
We await review comments from the journal on our paper. We have had numerous requests for advance copies. The results of this analyses have been very useful in our efforts to select filters for a new HVAC technology being developed for DOE-NETL and for our selection of filters for an energy-efficient HVAC system used in a California Energy Commission-supported study of relocatable classrooms.

Task Ventilation Optimization (DOE IVIAQ Task 3.8)
Sponsor(s): DOE-EE
Collaborator(s): none

Background
In prior years, we have investigated the ability of several task ventilation systems to provide better ventilation, and reduced pollutant levels, at the breathing zone, relative to conventional ventilation systems with well-mixed indoor air. The results of the most recent set of experiments were quite promising. All of the commercially available task

ventilation systems have been designed to provide local control of thermal comfort. Improved ventilation at the breathing zone has been an incidental feature of these systems. Starting in the second half of FY2000, we initiated experiments and modeling to optimize ventilation performance. Rather than evaluate commercial products that have not been optimized for ventilation performance, we will design and evaluate new technologies for supplying air near the occupant. As of the end of FY2000, an initial set of parametric studies had been completed to provide qualitative visual images of the airflow patterns between the task ventilation system's air outlet and the breathing zone of a heated mannequin. We also started developing the software for computation fluid dynamics (CFD) modeling of these systems. A post doctoral fellow, Seung Min Lee, started working on this effort during September 2000.

May 2001

Experiments: An additional cooling coil was added to the experimental system used for our task ventilation studies to increase cooling of the room. Data were examined and we found that the drift in instrument response exceeded our expectations. We determined that an increased warm up period for the mass spectrometer and normalization of the tracer gas data with the instrument response for nitrogen, resulted in satisfactory instrument performance. Five tracer gas step-up experiments were completed to measure air change effectiveness. Fans mixed the air thoroughly in one quality assurance test. The other four experiments varied the angle of air supply and maintained the supply flow rate constant at 5 L/s. Data analyses are underway.

Modeling: The CFD model of the experimental task-ventilation experiment is running and we are attempting to get a converged solution that gives sensible results. Specifying a 75 Watt heat lose from the manikin as a purely convective loss results in skin temperatures that are unreasonably high. The boundary conditions have been modified to account for radiation effects. We are still waiting for an answer.

HyPak Project

Sponsor(s): Davis Energy Group

Collaborator(s): LBNL Building Technologies Department, Davis Energy Group, Des Champs Laboratories, Arthur D. Little

Background:

The Davis Energy Group as prime contractor received an award from NETL to develop a Hydronic Packaged Rooftop Unit (HyPak) that replaces conventional rooftop packaged units but saves energy and improves indoor air quality. The Hypak is designed primarily for climates with a low or moderate humidity. The IED's role in this project is to devise the technology for real-time integrated measurements of the rate of outside air supply, to select the filtration option, and to contribute to a field study of the units IAQ performance.

May 2001

Our primary effort in May was to complete a report for Davis Energy Group on the work completed to date related to filter selection and control of outside air flow.

D. Indoor Environmental Quality and Energy Efficiency in Relocatable Classrooms

Improving IAQ and Saving Energy in Relocatable Classrooms
Sponsor(s): California Energy Commission
Collaborator(s): Davis Energy Group, Pacific Gas and Electric Company

Background

In this study, Element 6 of the California Energy Commission (CEC) funded High Performance Commercial Buildings Systems Program, we will investigate and demonstrate how the application of building science and ventilation engineering can lead to simultaneous building energy savings and indoor environmental quality performance improvements. This project focuses on developing and testing a concept for high-performance relocatable classrooms (RCs). RCs, otherwise known as "School Portables," or "Modular Classrooms," are very common in California. RCs provide school districts with quick and convenient means of adding or replacing classrooms. RCs can be moved around, reducing unnecessary classroom construction. Currently the State of California mandates that at least 20% of new classrooms be RCs.

In this project we will evaluate the benefits of a novel building ventilation system and also of selecting construction materials that emit fewer indoor pollutants. We will construct and study three or four RCs sited in California school districts. One project will test a high-performance ventilation and air conditioning system, the Indirect-Direct Evaporative Cooler (IDEC), suitable for warm dry climate zones of California. In these climates, IDEC offers potential cooling energy savings of about 70% compared to the standard (10 SEER) air conditioner used in RCs. In addition to energy savings the IDEC provides a continuous flow of outside air that will improve the indoor air quality of the RCs. For heating, an energy-efficient natural gas-powered hydronic loop will be integrated into the IDEC ducting system. A second project will focus on identifying RC materials that are VOC sources through chamber measurements in RCs. Two RCs tested in the field will be constructed using materials selected for lower VOC emissions. The project will also include an effort to develop, test, and refine computer models of RC energy performance in California. Data from the field study will be used to validate the computer simulations and upgrade inputs to the model. Energy and cost-benefit projections will be made for different California climate zones.

May 2001

Progress was made in all planned activities. Final preparations for fieldwork and RC construction were made. We continued to coordinate with two school districts and the RC manufacturer. Purchases of materials, supplies, and instrumentation for the fieldwork were completed. The field-monitoring plan was updated.

E. Airflow and Pollutant Dynamics in Buildings

Particle Deposition to Indoor Surfaces
Sponsor(s): DOE-CBNP, LLNL
Collaborator(s): U.C. Berkeley, Dept. of Civil and Environmental Engineering

Background
Inhalation exposure to airborne particles can have adverse health effects. One fate for particles in indoors is deposition onto surfaces. Clearly, this process alters the likelihood of human exposure, since a deposited particle cannot be inhaled unless re-suspended. Knowledge of the rates of particle deposition onto indoor surfaces and the factors governing those rates is therefore important.

May 2001
No work was performed on this project in May.

Particle Deposition in Ductwork
Sponsor(s): DOE-CBNP, LLNL
Collaborator(s): U.C. Berkeley Dept. of Civil and Environmental Engineering

Background
The effort under this part of the project is aimed at developing a computational predictive ability for dispersion of gases and aerosols in large indoor spaces. Such a predictive capability will allow development of exit strategies, as well as containment strategies for an unexpected pollutant release in an indoor large space. We are also interested in obtaining an improved understanding of pollutant dispersion in large indoor spaces to reduce occupant exposures under a variety of scenarios.

May 2001
M. Sippola has completed deposition experiments of 5µm particles in the experimental duct apparatus at Reynold's numbers of 21,000, 52,000 & 89,000. Problems were discovered at the high flow rate (bulk velocity = 8.9 m/s, Re = 89,000)due to resuspension of particles deposited on fan blades in previous experiments. Thorough cleaning of the duct apparatus and of the fan and fan housing solved the resuspension problem. Data for 5µm particle deposition follows a trend established by previous experiments with 1 and 3 µm particles: measured deposition to the duct floor agrees well with theory while measured deposition to the duct wall and ceiling is greater than predicted by one to several orders of magnitude. In addition, a shrouded aerosol sampling probe has been built and is now being used in conjunction with a TSI Aerodynamic Particle Sizer (APS) during experiments in the duct apparatus. The shrouded probe performance is being evaluated prior to use in field investigations of HVAC systems in real buildings.

M. Sippola has also worked on developing Fortran programs to implement various types of models presented in the aerosol deposition literature. Several 'free flight' models, two 'down sweep' models, and two stochastic models have been successfully implemented to predict particle deposition under the conditions of the experimental duct.

Particle Penetration through Building Cracks
Sponsor(s): DOE-CBNP, LLNL
Collaborator(s): U.C. Berkeley Dept. of Civil and Environmental Engineering

Background
The goal of the particle penetration through building cracks investigation is to explore the extent to which particles in infiltrating air remain airborn as the air passes through the building envelope. The work started with modeling, and now includes experiments to validate the predictions. We have finished the idealized crack experiments and will embark on realistic building cracks soon. These results are expected to help us gain insight on the protection of building shell might offer, especially for air leakage dominated buildings.

May 2001
In May, De-Ling Liu finished the measurement of particle penetration through cracks in six different building materials (plywood, oriented-strand board, pine, redwood, concrete, and brick) using APS and EAA. APS is used for particles greater than 0.6 micron and EAA for submicron. Polydisperse particles are generated by atomizers for the experiments. The experimental data show agreement with our predictions for most cracks. However, for rougher surfaces such as concrete and oriented-strand board, the measured penetration factors was observed lower than predicted by ~ 20 % for 0.1-0.4 micron particle size.

A new set of experiments using a cracked brick will be performed next month.

Multizone Simulation and Model Development
Sponsor(s): DOE-CBNP, LLNL
Collaborator(s): U.C. Berkeley Dept. of Civil and Environmental Engineering, Dept. of Architecture

Background
This task seeks to develop and implement models for pollutant transport in buildings. This includes coupling the COMIS multizone airflow program with the MIAQ4 aerosol dynamics model. The model development effort aims to improve our capabilities for predicting gas and aerosol transport in heterogeneous multi-room indoor environments. The models have two major applications: (1) as tools used directly to predict airflow and pollutant transport in buildings; and (2) as testbeds to check our

understanding of the physical processes that explain experimental data on pollutant transport.

May 2001

L. Mora returned to the University of La Rochelle. We expect continued close collaboration on projects outlined in previous months. In particular, this will include coupling CFD codes to COMIS-style network models.

D. Lorenzetti completed a network model for a problem of pollutant transport in a large indoor space. For the network model to predict bidirectional flow (between the upstream and downstream sides of the large space), it required an assumed floor-to-ceiling temperature profile, which had to differ on both sides of the room. The calculated flows were sensitive to the assumed profile. Ultimately the temperatures were taken from the zonal model predictions, despite the fact that they would not be available to an analyst using only network models. In connection with this project, an error in the boundary conditions for the original zonal calculations was discovered and fixed.

M. Sohn presented a draft of a paper on using COMIS and MIAQ4 to predict size-resolved transport of pollutants in a residence. In one interesting result, he demonstrated how to improve the simulation of small-chamber experiments, by modeling the removal of environmental tobacco smoke due to the sampling mechanism used in the test facility.

T. Thatcher and E. Wood set up an experimental apparatus for tests on flow through large horizontal apertures. The test rig was built last summer, and used for initial qualification tests, before being dismantled due to space and time restrictions in the lab. With a new summer student arriving in June, some necessary changes to the apparatus will help prepare it for the main round of tests.

Prototypical Building Characterization

Sponsor(s): DOE-CBNP

Collaborator(s): None

Background

This project's goal is to develop building management strategies to reduce occupant exposures to an unexpected release of a toxic aerosol or gas. The release could be indoors or in the building vicinity. Our approach is to develop prototypical model buildings that represent the general building stock and to use them to simulate hypothetical pollutant releases. The concentration predictions will help us understand how pollutants are expected to distribute in a building and how event-specific uncertainties might affect the generalizations. Rules-of-thumb response strategies will be developed based on the model predictions. We are currently developing response strategies for commercial office buildings.

May 2001

M. Sohn has received comments from, and responded to, reviewers of a journal manuscript titled, "Responding to Sudden Pollutant Releases in Office Buildings: 1. Framework and Analysis Tools" by M. Sohn, R. Sextro, and A. Gadgil. The revisions will be reviewed by the authors and re-submitted to the journal Indoor Air.

M. Sohn has completed a revision of the presented a draft of a paper on using COMIS and MIAQ4 to predict size-resolved transport of pollutants in a residence. In one interesting result, he demonstrated how to improve the simulation of small-chamber experiments, by modeling the removal of environmental tobacco smoke due to the sampling mechanism used in the test facility.

Air Flow and Pollutant Dispersion in a Large Room
Sponsor(s): DOE-CBNP, LLNL
Collaborator(s): None

Background

We are using a combination of computational fluid dynamics (CFD) modeling and experimental work to advance CFD models for use in buildings and to help us to develop a simpler "lumped parameter" model for air flow and pollutant dispersion in a single, large room, *e.g.*, an auditorium, to incorporate into COMIS. This work also involves collaboration with scientists in France who are developing CFD models.

May 2001

C. Lobscheid completed a fully recirculating pollutant model and was able to model 12 of the experiments completed previously. Comparison between CFD results and experiment are promising. The CFD code tends to under-predict the mixing time. The "power law" relation between the mixing time and the input of mechanical energy into the room is well predicted as is the relationship between mixing time and turbulent kinetic energy.

Christian Lobscheid has completed his CFD calculations for mixing time for the experimental cases found in the Drescher dissertation. He is now writing a report on this work; the report will be his Master's Thesis.

Marc Abadie and Elizabeth Finlayson attended the StarCD North American Users Meeting in Detroit. This is a useful opportunity to talk with the principals, developers, and users of StarCD, the computational fluid dynamics code we are using.

Airflow, Heat and Mass Transport in Tunnels
Sponsor(s): DOE-OCRWM.
Collaborator(s): None

Background

Computer programs in the TOUGH2 family of codes simulate the flow of multicomponent, multiphase fluids in porous and fractured media. This project seeks to add a tunnel model to TOUGH2.

Tunnels carry heat and moisture via the movement of air, whether it is forced by fans, or set up by natural convection. These processes differ both in kind and in speed from the heat conduction and seepage of moisture through native rock. Thus, coupling a tunnel model to TOUGH2 will provide an important new capability for predicting how excavated engineering systems affect transport in geologic media.

Researchers at LBNL use TOUGH2 to model heat and mass transport in Yucca Mountain, the site of a proposed geological repository for storing spent nuclear fuel. The excavation model will support physics specific to Yucca Mountain, including changes in the airflow due to the presence of waste packages in storage tunnels.

May 2001

This project began in May. A. Gadgil formed a work group to conduct research on modeling heat and moisture transport in a tunnel network at Yucca Mountain. The team includes Marc Abadie, Phillip Price, Michael Sohn, David Lorenzetti, and Ashok Gadgil from the Airflow and Pollutant Transport group; Shaheen Tonse from the Advanced Energy Technologies Department; and Brian Smith from Energy Performance of Buildings group.

D. Lorenzetti and A. Gadgil, along with scientists from the Earth Sciences Division, visited the site of the proposed repository.

F. Service to Professional and Governmental Organizations (DOE IVIAQ Task 3.2)

ASHRAE

Sponsor(s): DOE-EE

Collaborator(s): none

Background

Bill Fisk serves on ASHRAE's Environmental Health Committee (EHC's), as chairman of the EHC's Research Subcommittee, and on ASHRAE's IAQ'2001 Organizing Committee.

May 2001

Bill Fisk reviewed a paper for the IAQ2001 conference and started preparations for the EHC meeting to be held in June.

Indoor Air 2002 Organizing Committee

Sponsor(s): DOE-EE, AIHA, and many other sponsors
Collaborator(s): U.C. Berkeley, California Department of Health Services

Background

The Indoor Air 'xx conference, held every three years, is the largest and most prestigious international indoor air quality conference. Hal Levin, Bill Nazaroff, Bill Fisk, Rich Sextro, and non-LBNL staff are serving on the organizing committee for the Indoor Air 2002 organizing committee, with Hal Levin serving as the Conference President. DOE contributed $30K during FY2000 to the organization of this conference. Support from a large number of sponsors is anticipated.

May 2001

Preparations for the Indoor Air 2002 Conference are intensifying. During May, the call for abstracts and papers was completed and sent to the printer. The document was also placed on the web site. Visits to the web site increased to 250 per week and the conference President is now receiving many telephone inquiries. The organizing committee met to plan the plenary presentations. A set of plenary topics was established and committee members are making preliminary inquiries with potential speakers.

OUTSIDE CONTACTS

May 2001

Bill Fisk continued to hold discussions with Jim Cole at CIEE and Martha Brook and Nancy Jenkins at CEC about an effort to identify priority energy related IEQ research needs for CEC, ASERTTI, and DOE. He also contacted numerous individuals about participation in this effort.

INDOOR ENVIRONMENT DEPARTMENT

3. Healthy Buildings and Productivity Studies

W.J. Fisk
510-486-5910

A. Experimental Healthy Buildings and Productivity Research

Healthy Buildings Intervention Study (DOE IVIAQ Task 4.2)
Sponsor(s): DOE-EE, NIOSH, EPA
Collaborator(s): NIOSH

Background

LBNL and NIOSH have conducted a blinded-controlled intervention study in an office building to evaluate the effects of enhanced particle filtration systems, improved surface cleaning, and air temperatures on health symptoms. The filtration intervention involved switching on a weekly basis between typical and high efficiency filters on two floors of an office building. On Thursday or Friday afternoon of each week, occupants reported their health symptom intensities for the current day. Extensive environmental measurements were performed throughout the study. After the seven-week filtration intervention study, a surface cleaning intervention, consisting of special intensive vacuuming of floors and chairs, was performed on one floor with the occupants of the second floor serving as the control group. A third "natural experiment" occurred throughout the study due to natural temporal variations in indoor air temperatures. A short paper on the filtration intervention was published in FY2000.

May 2001

Comments on our paper were received from the Journal. We have been asked to shorten the paper, however, there were very few comments on the content or substance of the paper. Mark Mendell is working on the revisions.

Ventilation Rate Intervention Study (DOE IVIAQ Task 4.3)
Sponsor(s): DOE-EE
Collaborator(s): Center for the Built Environment

Background

In this study, we are quantifying the relationships of worker performance in a call center with building ventilation rate and air temperature. Worker performance is being determined from the automatically recorded telephone call data at three relatively constant outside-air ventilation rates, and also with the economizer system operating. The minimum ventilation rate corresponds to applicable code requirements. Periods of steady ventilation rates range from one week to one day. Indoor air temperatures and

building occupancy fluctuate naturally. Temperatures, humidifies, carbon dioxide concentrations, and VOC concentrations are being monitored.

May 2001
We made progress on both tracks of the data analyses. In analyses of group performance, we examined work performance for advice nurses versus the difference between indoor and outdoor carbon dioxide concentration, while controlling for time (day, week), temperature, humidity, and the queue of incoming calls. With five carbon-dioxide ranges, we see evidence of increased performance with decreased carbon dioxide. Work speed is about 3% higher at the lowest carbon dioxide concentration (<100 ppm above outdoor concentration), relative to the highest concentration (> 310 ppm above outdoor concentration). These results are still preliminary. For example, we still plan to control for quality of the workforce at each concentration range. The analyses of changes in individual performance suggest a larger productivity change with changing ventilation rate; however, in these analyses we have yet to control for any confounders.

B. Literature Reviews and Assessments

Association of HVAC Type and Features with SBS Symptoms (DOE IVIAQ Task 4.8)
Sponsor(s): DOE-EE
Collaborator(s): Helsinki University of Technology

Background
Cross-sectional studies from around the world have investigated the relationship of HVAC system type in commercial buildings with occupant health symptoms. LBNL and the Helsinki University of Technology are collaborating on a critical review of the literature. This document will summarize the findings of studies that satisfy study quality criteria and review the evidence supporting or refuting the hypothesized explanations for the observed associations.

May 2001
We received comments of the journal's reviewers on our paper and Bill Fisk and Olli Seppanen revised and resubmitted the paper.

Health and Productivity Reviews
Sponsor(s): DOE-EE
Collaborator(s): None

Background
In this area of work, critical reviews are performed to assess the opportunities for health and economic gains from improvements in indoor environmental quality.

May 2001

At a joint symposium of the American Thoracic Society (ATS) and American Lung Association (ALA), Bill Fisk made a presentation on the potential improvements to health from better IEQ. The associated economic benefits were also presented. The ATS / ALA meeting is attended by a very large number of health researchers and health-care providers.

IAQ and Health in Schools (DOE IVIAQ Task 4.7)
Sponsor(s): DOE-EE
Collaborator(s): University of Minnesota

Background

In 1999, the IED, working with Bill Angel at the University on Minnesota, completed a report on a broad review of IAQ and associated health problems in schools. A conference article based on this review was presented in FY1999. The FY2001 plans are to complete and submit a journal article based on this work.

May 2001

There was no substantive activity on this topic during April.

C. Analyses of Data from the EPA BASE Study (DOE IVIAQ Task 4.4)

VOCs and SBS Symptoms
Sponsor(s): DOE-EE
Collaborator(s): EPA developed the database for these analyses

Background

EPA has collected a large set of data from office buildings, including building characteristics, air pollutant concentrations, and SBS symptom prevalences. We have used statistical models to analyze data from the first set of buildings and learn about the associations of volatile organic compounds with symptoms. The analysis will now be extended, using the data from all 100 buildings.

May 2001

Kate Steiner graduated from UC Berkeley and completed her tenure as GSRA at LBNL. Her efforts led to a complete set of BASE VOC data that await upcoming analyses.

Carbon Dioxide and SBS Symptoms
Sponsor(s): DOE-EE
Collaborator(s): U.S. EPA

Background

For this task, we are using multivariate statistical models to analyze data from the EPA BASE study to investigate the association of indoor carbon dioxide concentrations with SBS symptom prevalences.

May 2001

Two pre-proposals for new BASE study data analyses were prepared by Mark Mendell and Bill Fisk and forwarded to EPA for review. Kate Steiner graduated from UC Berkeley and completed her tenure as GSRA at LBNL. Her efforts led to the extension of CO_2 / SBS symptom regression analyses for the 100 building dataset.

D. Service To Professional And Governmental Organizations

National Occupational Research Agenda

Sponsor(s): DOE-EE supports time of LBNL staff serving on the National Occupational research Agenda Indoor Environment Team.

Collaborator(s): Broad representation on Committee from government, universities, labor

Background

Bill Fisk is participating in the activities of the National Occupational Research Agenda (NORA) Indoor Environment Team. The objectives of this interdisciplinary team established by NIOSH are to develop a priority research agenda related to IAQ and health in non-industrial occupational buildings, and to foster partnerships and collaborations as needed to implement the research agenda. This multi-disciplinary team is developing a paper on the highest priority research needs related to IAQ and health in non-industrial occupational environments.

May 2001

Bill Fisk attended a meeting of the NORA IEQ team held in Washington DC. During the first day, the team developed a two-page briefing document based on our research needs document. During the second day, the team met with a variety of outside individuals to discuss how to build collaborations and garner support for the Team's research agenda.

California IAQ Interagency Working Group

Sponsor(s): DOE-EE supports the participation of LBNL staff in these meetings

Collaborator(s): Broad representation from the sponsors and performers of IAQ research in California

Background

The California Interagency Working Group (CIAW) meets quarterly to maintain communication on IAQ activities in California. Mike Apte serves as LBNL's representative.

May 2001

M. Apte participated in May at DHS in Berkeley. IEP is to send a revised project description to DHS for meeting minutes.

OUTSIDE CONTACTS

May 2001

We continued discussion with United Technologies about potential research collaborations.

Bill Fisk also provided input regarding the use of ASHRAE Standard 129 in conjunction with credits for the Green Buildings Council LEEDs, Commercial Interiors project.

INDOOR ENVIRONMENT DEPARTMENT

4. EXPOSURE AND RISK RESEARCH

T.E. McKone, W.J. Fisk, A.T. Hodgson, R.G. Sextro
486-6163

A. Environmental Tobacco Smoke Research

Further Characterization of Environmental Tobacco Smoke
Sponsor(s): California Tobacco-Related Disease Research Program
Collaborator(s): None

Background

In this project, led by Rich Sextro, laboratory and field research is being conducted to assess the usefulness of particle-bound components of ETS as tracers for exposure assessment studies.

May 2001

Work continued on the project final report and a journal manuscript. Modeling effort on smoking chamber nicotine data was continued. Promising approaches for new miniature area and personal ETS particle exposure monitors were incorporated into a proposal submitted to the LBNL Director's office for consideration as a Laboratory Directed Research and Development project. Its objective is development of miniature particle exposure monitoring devices for mass, with discrimination between environmental tobacco smoke and vehicle exhaust. A research plan was drafted in collaboration with the Palo Alto Research Foundation Institute for ETS monitoring in the homes of asthmatic children.

Vapor-Phase Organics in Environmental Tobacco Smoke
Sponsor(s): California Tobacco-Related Disease Research Program
Collaborator(s): U.C. Berkeley Department of Environmental Engineering

Background

Brett Singer and Al Hodgson are working on this project with assistance from several undergraduate students in the U.C. Berkeley Environmental Engineering Department. The project focuses on quantifying human exposure to vapor-phase organic compounds in ETS under a range of realistic smoking patterns and ventilation rates. Special attention is being paid to sorption processes that can have a large impact on airborne concentrations of semi-volatile organic compounds (SVOCs; *e.g.*, nicotine) both during and long after active smoking periods.

May 2001

We completed the second long-term smoking experiment in which cigarettes (five cigarettes per day) were smoked seven days per week for four weeks without a break in the furnished model room operated at a ventilation rate of 2 h^{-1}. Air samples for toxic and tracer compounds were collected throughout this period. Additional samples are being periodically collected following the conclusion of the experiment to measure the re-emission of the less volatile compounds. We completed and submitted the project annual report to the sponsor on schedule and received authorization to carry our unexpended funds forward into the next California State fiscal year. We completed the manuscript entitled, "Vapor-Phase Organics in Environmental Tobacco Smoke: 1. Effects of Smoking Rate, Ventilation, and Furnishing Level on Apparent Emission Factors." The manuscript was given to internal reviewers for comment prior to submitting it to *Environmental Science & Technology*.

B. Performance of Smoking Rooms

Sponsor(s): California Tobacco-Related Disease Research Program
Collaborator(s): California Department of Health Services

Background

The IED and the California Department of Health Services (CDHS) are studying the performance of smoking rooms. Laboratory studies will assess the rate of ETS leakage from a smoking room to the adjoining space as a function of smoking room physical characteristics, door usage, and temperature and pressure differences. A mathematical model of smoking room performance will be developed and model predictions will be compared with measured data. A final phase of the project will assess the accuracy of the model in predicting the performance of smoking rooms located in a small number of office buildings.

May 2001

Our major effort during May was to further analyze data and prepare our annual project report for the sponsor. In the course of this activity, we devised a new performance metric for smoking rooms called the smoking room protection factor. This factor compares the predicted ETS concentration in the non-smoking area (if smoking occurred in that area), to actual measured concentration in the non-smoking area when smoking is restricted to a smoking room. Based on our experiments and modeling, the smoking room reduces ETS concentrations in the non-smoking area by a factor of 1.9 to 34. Analysis of the laboratory results has resulted in quantification of the various types of leakage flows, the effect of these leaks on smoking room performance and non-smoker exposure, and the relative importance of each leakage mechanism. The results indicate that the first priority for an effective smoking room is to maintain it depressurized with respect to non-smoking areas. If this goal is achieved, the most significant ETS leakage source is the pumping action of the smoking room door whenever it opens.

C. The California Exposure Modeling Research Center

A Multi-Domain Framework for Integrating Models and Measurements of Multimedia Environmental Contaminants
Sponsor(s): U.S. EPA National Exposure Research Laboratory
Collaborator(s): U.C. Berkeley, Stanford University

Background
Tom McKone, Deborah Bennett, Neil Klepeis, Randy Maddalena, William Riley, and Agnes Bodnar are working on this project at LBNL; Wayne Ott and Paul Switzer are working on this project at Stanford University; and William Nazaroff, Katharine Hammond, and Michael Tarter participate through U.C. Berkeley.

The goal of this project is to develop and apply models to improve the process of exposure assessment in two ways. First is to provide a more complete picture of how humans are exposed to a number of important pollutants. Second is to determine the level of precision that is feasible for quantifying human exposure to these pollutants. These efforts are being organized around two research components: (1) an indoor/outdoor model for total human exposure to particulate matter (PM); and (2) development and evaluation of source-to-dose models for persistent pollutants. These two components include a number of research areas.

May 2001
M. Sohn has developed a skin absorption model for incorporation into his multi-compartment pharmacokinetics model. For this model, skin is treated as a diffusion barrier between the skin surface and blood. This differs from treating the skin as a storage compartment, as is done in the EPA two-compartment skin model. The reduced model relies on fewer adjustable input parameters, but provides a reasonably accurate description of the dermal exposure route for the purposes of our exposure assessment research.

W. Riley and T. McKone continued to work on a dose model that relates intermittent contact with contaminated surfaces to dermal uptake and dose. In May, the model was modified to include the partition coefficient between stratum corneum and epidermis. Riley also worked on a method that applies a 'phantom' control volume at the interface between the stratum corneum and viable epidermis to force the resulting solution matrix to remain tridiagonal. Riley and McKone together with Ed Furtaw and Curt Dary of EPA Las Vegas developed and submitted an abstract on our dermal research for presentation at the International Society of Exposure Analysis Annual Meeting in November 2001. The title of the proposed presentation is "Modeling Absorbed Doses from Intermittent Dermal Contact."

R. Maddalena, A. Bodnar and T. McKone continued to work on a revised framework for linking the concentration of “air toxics” in crops to the exposure concentration at the

point of contact. Over the past few decades, the modeling community has improved the reliably of models that estimate the uptake of pollutants into vegetation. However, without being able to characterize or approximate the flows of food from farm-to-plate, even in very general terms, the information about concentrations in vegetation (measured or modeled) will not be as useful as it could be for source-to-dose evaluations. In May, we began to assess the available information to determine if a simple approach can be developed that reduces the crop/food distribution process to a relatively simple mass flow relationship. Maddalena, Bodnar, and McKone developed and submitted three abstracts on food pathway research for presentation at upcoming conferences. The first, prepared for the Society of Environmental Toxicology and Chemistry, is entitled "Exposure Pathways and 'Food-Sheds' in Continental Scale Source-to-Dose Modeling." The second and third abstracts were prepared for the International Society of Exposure Analysis Annual Meeting in November 2001 and are entitled "Tracking the Transfer of Air Emissions to Food: Exposure Pathways and 'Food-Sheds' in Multi Pathway Source-to-Dose Modeling" and "Accounting for Locally Grown Foods in Cumulative Exposure Assessments."

R. Maddalena and T. McKone revised their manuscript entitled "Exposure Chamber Measurements of Mass Transfer and Partitioning at the Plant/Air Interface" to address reviewer comments. The journal *Environmental Science & Technology* has tentatively accepted the paper for publication pending this response.

P. Switzer and W. Ott (Stanford collaborators) explored the use a theoretical indoor-outdoor averaging-time model for simulating air quality concentration time series measurements collected in the San Francisco Bay Area. The theoretical averaging time model is derived from the mass balance equation used to model indoor and outdoor air-pollutant concentrations. The model includes as inputs the indoor air exchange rate, the particle deposition rate, and the statistical properties of the ambient time series. The model includes the autocorrelation introduced by the indoor setting itself and the autocorrelation present in the ambient outdoor data, and it predicts the autocorrelation structure of the indoor time series and its variance as a function of averaging time. To evaluate this model using measured concentrations, they are examining the averaging time relationships for particulate and gaseous air pollutant data measured in residential locations using real-time monitoring instruments with high time resolutions (1-minute and 5-minute intervals). By forming time-averaged concentrations from these real-time data for 1 hour, 2 hours, or some other selected number of hours, they hope to compare statistics of the empirical measurements with the predictions of the theoretical averaging time model.

N. Klepeis carried out a sensitivity analysis for a two-compartment indoor air quality model in order to optimize the model with tracer pollutant data collected in two residences. He also conducted a sensitivity analysis of size-resolved environmental tobacco smoke (ETS) emissions from cigars and cigarettes with respect to different

particle-counting measurement techniques and the validity of total integrated particle mass collected on a filter.

A. Bodnar completed a preliminary spatial regression analysis of annual average ambient concentrations of benzo(a)pyrene in California using data supplied by the California Air Resources Board. She selected several explanatory variables to predict concentration. Among the variables used are county level population density, median household income, vehicles/household, fraction of households with public gas/bottled gas/electric/coal wood use, and crop acreage, as well as three dummy variables including coastal county, Bay Area county, or Northern California county. The resulting model fit quite well (r^2= 0.88) by ordinary least squares. Bodnar is now working on a reduced parameter model (since over-fitting may have occurred). Further, a simultaneous auto-regressive model was used to generate the final spatial regression model, without any remaining spatial autocorrelation of the residuals. In the future, as data become available, the analysis will be applied to other airborne emitted PAHs in order to explore the relationship between concentration levels and human exposure.

W. Riley and J. Marshall continued to work on quantifying source-to-dose relationships for CO and benzene in the LA basin. In May, they collected data on emissions of benzene and CO during the 90's in the South Coast air basin. These were integrated with ambient concentration data to predict dose-emission ratios in the basin.

M. Sohn and T. McKone together with Marc Rigas Jerry Blancato of EPA Las Vegas and Frederick Power and Andrew Tsang of Anteon Corporation developed and submitted an abstract for presentation at the International Society of Exposure Analysis Annual Meeting in November 2001. The title of the presentation is "Reconstructing Exposure Scenarios Using Dose Biomarkers. An Application of Bayesian Uncertainty Analysis."

T. McKone worked with Haluk Ozkaynak of the EPA and Paul Lioy of Rutgers University to develop a special symposium on source-to-dose modeling for the November Meeting of the International Society of Exposure Analysis.

D. Total Risk Integrated Methodology (TRIM) Project

TRIM.FaTE Project
Sponsor(s): U.S. EPA Office of Air Quality, Planning and Standards
Collaborator(s): Oak Ridge National Laboratory, University of Tennessee, ICF Consulting

Background
Randy Maddalena, Tom McKone, Deborah Bennett, and Agnes Bodnar are working on this project. The Total Risk Integrated Methodology (TRIM) is an EPA project to develop models and data for assessing the multimedia residual health and ecological risk from pollutants released to air sheds. The LBNL team is working on two

components of the TRIM project: (1) testing, evaluation, and validation of the TRIM.FaTE module; and (2) development of the TRIM.Expo multimedia, multipathway exposure model.

May 2001

R. Maddalena and T. McKone continued to work on detailed audits of algorithms used in the TRIM.FaTE model. They compared the algorithms and parameters in the model code to those reported in the TRIM technical support document and provided written comments on necessary modifications/corrections.

T. McKone and R. Maddalena participated in four TRIM conference calls (May 2, 9, 16 and 30) and responded to several e-mail questions about the model-evaluation process.

E. Criteria for Evaluation and Development of Probability Density Functions for a Set of Human Exposure Factors

Exposure Factor Distributions
Sponsor(s): U.S. EPA Office of Emergency and Remedial Response
Collaborator(s): None

Background

Randy Maddalena, Tom McKone, and Agnes Bodnar are working on this project. The Office of Emergency and Remedial Response (OERR) plays a lead role in developing national guidance and planning future activities that support the EPA Superfund Program. The purpose of this project is to develop for OERR methods for scoring the quality, relevance, and reliability of probability density functions.

May 2001

R. Maddalena and T. McKone completed and submitted the draft final report of research performed during 2000-2001 for the Office of Emergency and Remedial Response (EPA Superfund program). The report is now going through EPA internal review. Once the EPA internal review is complete, the document will be sent for external review.

R. Maddalena and P. Price completed a short proposal for developing methods to relate the exposure factor data from short-term survey data to the information needed for probabilistic risk assessment (long term distribution of average intakes). The proposal was submitted to the EPA Office of Emergency and Remedial Response (OERR) for review.

F. Inter-Individual Differences in Metabolism of Carcinogens as a Risk Factor for Breast Cancer
Sponsor(s): U.S. Department of the Army
Collaborator(s): None

Background

The purpose of this project, led by Regine Goth-Goldstein, is to test for possible genetic factors that contribute to breast cancer risk, such as inter-individual variation in the level of enzymes that activate or detoxify environmental carcinogens. Variation in the level and activity of these enzymes can be due to mutations in the DNA sequences of the genes coding for these enzymes (genetic polymorphism) or to modification of gene expression by genetic and environmental factors. We have focused on the cytochrome P450 enzymes CYP1A1 and CYP1B1, both involved in activation of polycyclic aromatic hydrocarbons (PAHs). We are investigating whether the level of expression of these genes in breast tissue represents a risk factor for breast cancer.

May 2001

Two common genetic polymorphisms in the *CYP1B1* gene have been described that alter the activity of the gene product (the *CYP1B1* enzyme) to metabolize PAHs and also estrogens. These polymorphisms can be detected by PCR amplification of the region of the gene followed by treatment of the fragment with a restriction enzyme that digests the mutant, but not the wild type sequence. The protocol for detection of these polymorphisms was improved to distinguish between heterozygous and homozygous variants. The manuscript entitled "*CYP1B* expression, a potential risk factor for breast cancer" by R. Goth-Goldstein, Christine Erdmann and Marion Russell was submitted to *Cancer Research*.

G. Indoor Bio-aerosol Detection and Quantification by PCR

Sponsor(s): Laboratory Directed Research and Development (LDRD) Program
Collaborator(s): None

Background

The goal of this project is to develop and demonstrate a quantitative polymerase chain reaction (PCR) assay for rhinovirus, the virus that causes about half of common colds, and to use this assay to characterize the size distribution of human-produced droplet nuclei containing rhinovirus. Bill Fisk, Regine Goth-Goldstein and Marion Russell are working on this project.

May 2001

The internal standard, that will allow us to quantify the rhinovirus by PCR in a sample, was purified and quantified by fluorescence. The efficiency of the amplification reaction of the internal standard versus the viral RNA sample was determined using the LightCycler. The PCR products formed by the standard and the viral RNA sample were identical as determined by their melting temperatures. Therefore, the internal standard will accurately reflect the presence of the virus in the sample. A standard dilution curve was linear and indicated that up to ten virus copies in a sample are detectable.

H. Measurement of Semi-Volatile Organics in Ambient Air

Sponsor(s): U.S. EPA, EPRI, University of Texas, Washington State University
Collaborator(s): U.S. EPA, EPRI, University of Texas, Washington State University, Environment Canada, University of Washington, U.C. Berkeley, U.C. Los Angeles, Desert Research Institute, Restek Corporation, URG Corporation

Background

The objective of this project, led by Lara Gundel, is the development, validation, and application of new measurement methods for the accurate determination of semi-volatile organic pollutants in ambient air. Such species partition between the gas and particle phases in ways that complicate measurement and apportionment efforts. LBNL is contributing to several multi-investigator studies whose overall goal is the characterization of carbonaceous particles across the U.S.

May 2001

Work continued on the final report to the U.S. EPA and on several journal articles that present the results of recent validation studies for diffusion-based sampling methods for semi-volatile and particulate organic pollutants. We continued to participate in the characterization of particulate phase semi-volatile organic compounds in the Pacific Northwest. Diffusion-based indoor sampling continued in Seattle to assess the contribution of semi-volatile organic compounds to the large indoor sampling artifacts that are being observed in several cities. In collaboration with U.S. EPA, we continued the determination of semi-volatile alkanes and aromatic hydrocarbons in samples collected with the high capacity integrated organic gas and particle sampler during Texas Air Quality Study 2000. A journal article on the project is currently under internal review. Two presentations were prepared for the upcoming Gordon Conference on Atmospheric Chemistry.

A technology maturation proposal was completed and is being reviewed. The objective is to evaluate the potential adaptation of LBNL's novel air sampling technology to air pollution control in buildings. The project involves an informal collaboration with Supelco, a company with coating expertise.

The second patent has been granted to LBNL for air sampling technology. U.S. Patent 6,226,852: Method for fabricating a quantitative integrated diffusion vapor-particle sampler for sampling, detection and quantitation of semi-volatile organic gases, vapors and particulate components.

I. Traffic Study

Sponsor(s): California EPA, Office of Environmental Health Hazard Assessment (OEHHA)
Collaborator(s): OEHHA

Background

OEHHA is conducting a study of respiratory health of school children (4th and 5th grades) that reside and attend school in several California East Bay Area communities. OEHHA is attempting to determine whether the children's total exposures to traffic-related emissions are related to respiratory symptoms. LBNL is assisting OEHHA with the environmental measurements for the study. Our primary objectives are to identify markers for gasoline and diesel powered vehicle-related pollution and to make field measurements of these gaseous and particulate pollutants both indoors and outdoors at a set of East Bay Elementary schools throughout the remainder of the school year. Brett Singer, Tosh Hotchi and Al Hodgson are conducting this study.

May 2001

We completed simultaneous indoor and outdoor monitoring at the ten elementary schools. The indoor location at each school consisted of a single, randomly selected classroom. This monitoring effort was conducted in two phases with two groups of five schools each. We subsequently re-deployed the equipment to the outdoor locations at all ten schools and will continue to collect outdoor data until the conclusion of the school year in June. Several acts of vandalism resulted in loss of data. In one case, two sampling pumps and a CO monitor were destroyed.

We completed the project task to physically inspect all classrooms participating in the study and completed source and physical attributes checklists for these classrooms. The checklist data has been entered in a Microsoft Access database.

J. Building Characteristics that Influence Indoor Exposures to Outdoor Aerosols

Sponsor(s): EPA National Exposure Research Laboratory
Collaborators: None

Background

The goal of this project is to identify and characterize data sets for building characteristics that impact indoor concentrations of particles of outdoor origin. Concentrations of ambient particles indoors depend upon the fraction of particles that penetrate through the building shell or are transported via the HVAC system and the loss mechanisms that occur indoors, such as deposition.

May 2001

W. Fisk and W. Delp completed their input for Section 2.4 of the final report entitled "Building Characteristics that Influence Indoor Exposures to Outdoor Aerosols: Identification of Existing Data and Data Gaps". T. Thatcher and M. Sohn made updates to several sections of the draft report. . McKone, W. Fisk, and R. Sextro met to discuss a workplan for completing the report.

K. Other Efforts

May 2001
The Exposure and Risk Analysis Group held two group meetings:

- On May 3 – The group worked on planning and project reviews in preparation for submitting abstracts to the ISEA Conference.

- On May 18 – R. Goth-Goldstein described her work on expression of the *CYP1B1* enzyme as a risk factor for breast cancer.

R. Goth-Goldstein performed preliminary studies in collaboration with Dr. Eric Weyand from Rutgers University to test whether 7*H*-benzo[*c*]fluorene, which they believe to be an important DNA adduct forming PAH in complex mixtures such as coal tar, is activated to 7-hydroxy benzo[c]fluorene. They treated human hepatoma and breast tumor cells with either 7*H*-benzo[*c*]fluorene or 7-hydroxybenzo[c]fluorene and will determine if the two compounds lead to the same type of DNA adducts.

Ammonium and nitrate measurements were made for particles and materials impregnated to collect gases NH3 and HNO3 in Fresno Oct. 2000-Jan. 2001.

OUTSIDE CONTACTS

May 2001
T. McKone was appointed a member of the Advisory Council, American Center for Life Cycle Assessment.

In his capacity as head of the Society for Environmental Toxicology and Chemistry (SETAC) Specialty Group in Multimedia Fate Modeling, R. Maddalena reviewed and selected abstracts for several sessions for the November Annual SETAC Meeting.

On May 14, T. McKone presented the lecture "Introduction to Ionizing Radiation and Non-Ionizing Electromagnetic Fields," at the School of Nursing, University of California, San Francisco.

N. Klepeis attended the EPA National Exposure Research Laboratory (NERL) workshop on "Micro/Macro-Activity Data Needs to Improve Multi-Media, Multi-

Pathway Exposure/Intake Dose Assessments," on May 17 - 18, in Research Triangle Park, NC.

T. McKone, who has been appointed to the Magazine Advisory Board of the journal Environmental Science & Technology, attended the journal's editorial advisory board meeting on May 21.

T. McKone attended the Annual Meeting of the European Society of Environmental Toxicology and Chemistry (SETAC) May 6 - 10 in Madrid, Spain. At this meeting, the following platform presentations were authored or co-authored by members of the Exposure and Risk Analysis:

"Understanding and Characterizing the Source to Dose Relationship in LCA," M. Margni, D.H. Bennett, T.E. McKone and O. Jolliet.

"Source-to-Dose Relationships for Long-Range-Transport Pollutants," T.E. McKone, D.H. Bennett, R.L. Maddalena and A. Bodnar

"Who are the Worst Toxic Polluters? Human Toxicity Potentials for Life Cycle Assessment and Screening of Manufacturing Emissions," E. G. Hertwich, S.F. Mateles, W. S. Pease and T. E. McKone

"The Atmospheric Scale Height and Spatial Range of Multimedia Pollutant Fate Models," E. G. Hertwich and T. E. McKone

R. Goth-Goldstein met with Dr. Maira Caleffi, a breast surgeon in Porto Alegre, Brazil, and Christine Erdmann, to discuss details for initiating the project "Role of CYP1B1 in PAH-DNA adduct formation and breast cancer risk" that has been recommended for funding by the U.S. Army Medical Research Program.

L. Gundel met with John Paccione at Rupprecht and Patashnick Co., manufacturer of air sampling instrumentation, about opportunities to incorporate LBNL's sampling technology into their next generation of particle monitors.

L. Gundel had a meeting with Robert Shirey of Supelco.

L. Gundel also met with David Shelow at Restek Corp. and Sally Liu at University of Washington.

INDOOR ENVIRONMENT DEPARTMENT

5. International Energy and Environmental Activities

A.J. Gadgil
510- 486-4651

A. UVWaterworks
Sponsor(s): DOE-EE
Collaborator(s): None

Background

The UVWaterworks system uses ultraviolet (UV) light to treat water contaminated with bacteria, viruses, and Cryptosporidium. The technology, developed at the Lawrence Berkeley National Laboratory, has been licensed to WaterHealth International (http://www.waterhealth.com). DOE has supported limited field trials of the technology in South Africa, as part of DOE's participation in the SA-US-BiNational Commission.

May 2001

Ashok Gadgil worked with David McGraw (head of EHS Division) to develop a proposal to the Levinson Foundation for bringing LBNL science to improve social conditions in terms of drinking water quality in poor communities in hot humid tropics. Some of the proposed research will be undertaken in Mexican state of Guerrero, other in a Southeast Asian country.

B. Other Efforts

May 2001

Laurent Mora completed his research in simulation air flows and pollutant transport in the Indoor Environment department and returned to France.

Mathias Cehlin completed his internship with Indoor Environment on CT algorithm development and returned to Sweden.

Dr. Gavin Davies from Ove Arup office in London visited on May 7, 2001.

INDOOR ENVIRONMENT DEPARTMENT

6. Program Support and Administration

W.J. Fisk
510-486-5910

May 2001

Bill Fisk was formally appointed as the IED Department Head.

FY02 budget projections were distributed to all groups, assuming 20% and 40% reductions in support from DOE-EE.

The IED Principal Investigators meeting was held on May 21. In addition to the usual discussions, PIs met with Tommy Bangthamai, the new budget administrator for IED, and with other members of the budget team.

Bill Fisk met with all Group Leaders to develop a set of major research milestones for the next two years.

IED staff finalized LDRD proposals.

IED staff started to work on performance appraisals for staff.

An ad-hoc IED committee was established to develop recommendations on means of increasing the visibility of IED's work to sponsors and users of our research. Ashok Gadgil is serving as the committee chairperson.

7. STATUS OF FY2001 DELIVERABLES FOR DOE/OBT

Deliverable or Milestone	Due Date	Status
TASK 1. ENERGY PERFORMANCE OF BUILDINGS		
Completion of First Public Review of Standard 62.2	11/00	Completed
Preliminary Analysis of Air Leakage Database	1/01	Completed
Status report on Energy Efficiency Ventilation Demonstration Case Study	3/01	Completed
Recommendations regarding future participation of the US in AIVC	5/01	Completed
Second Public Review of Standard 62.2	7/01	
Technical paper on infiltration heat recovery	9/01	
TASK 3. VENTILATION AND IAQ CONTROL TECHNOLOGIES		
Submit paper on comparative assessment of particle air cleaning	11/00	Completed
Submit journal paper on a new approach for measuring the concentrations of VOCs in vinyl flooring	12/00	Completed
Submit journal paper on validation of a single-layer model to predict emissions rates of VOCs from vinyl flooring	3/01	Completed
Paper on literature review and product and practice survey for measurement and control of outside air supply by HVAC systems	7/01	
Conference paper on methodology for establishing health- and comfort-based criteria for VOC emissions from building materials	9/01	
Paper on task ventilation optimization studies	9/01	
TASK 4. HEALTH BUILDINGS AND PRODUCTIVITY RESEARCH		
Submit paper on IAQ, ventilation, and health in schools	10/00	Completed
Complete data collection in productivity field study	12/00	Completed
Article for ASHRAE Journal or equivalent on ventilation rates and health	6/01	
Paper on analyses of BASE Study data from 100 buildings	7/01	
Draft paper on productivity field study	8/01	
Expanded article on association of symptoms with high-efficiency filtration, temperature, and humidity is accepted for publication	9/01	Completed
Submit journal article on HVAC and health	9/01	Completed
TASK 5. ENERGY EFFICIENT FUME HOODS		
Technical paper on design development and test results of high-performance fume hood	6/01	
Article on high-performance fume hood for professional publication	12/01	
Task 6. IAQ Assessments of New Energy-Efficient Housing		
Submit journal paper on sources of formaldehyde and other VOCs in a new manufactured house	9/01	Completed